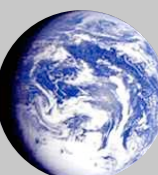
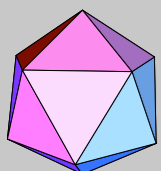
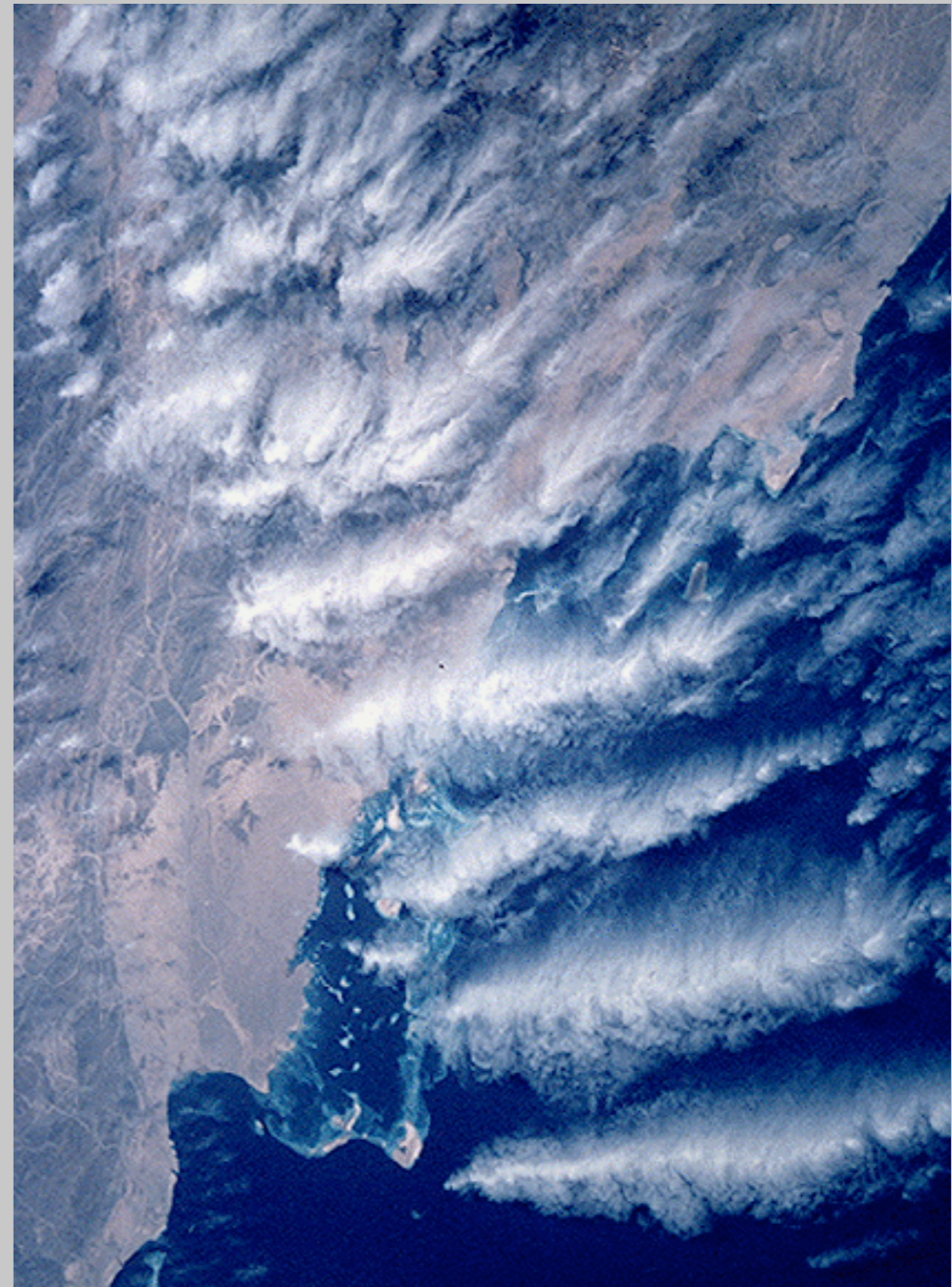


New results from the Super-Parameterization

***Jason Cole
Howard Barker
Marat Khairoutdinov
David Randall***

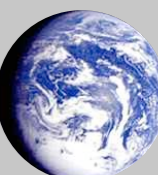
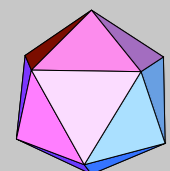
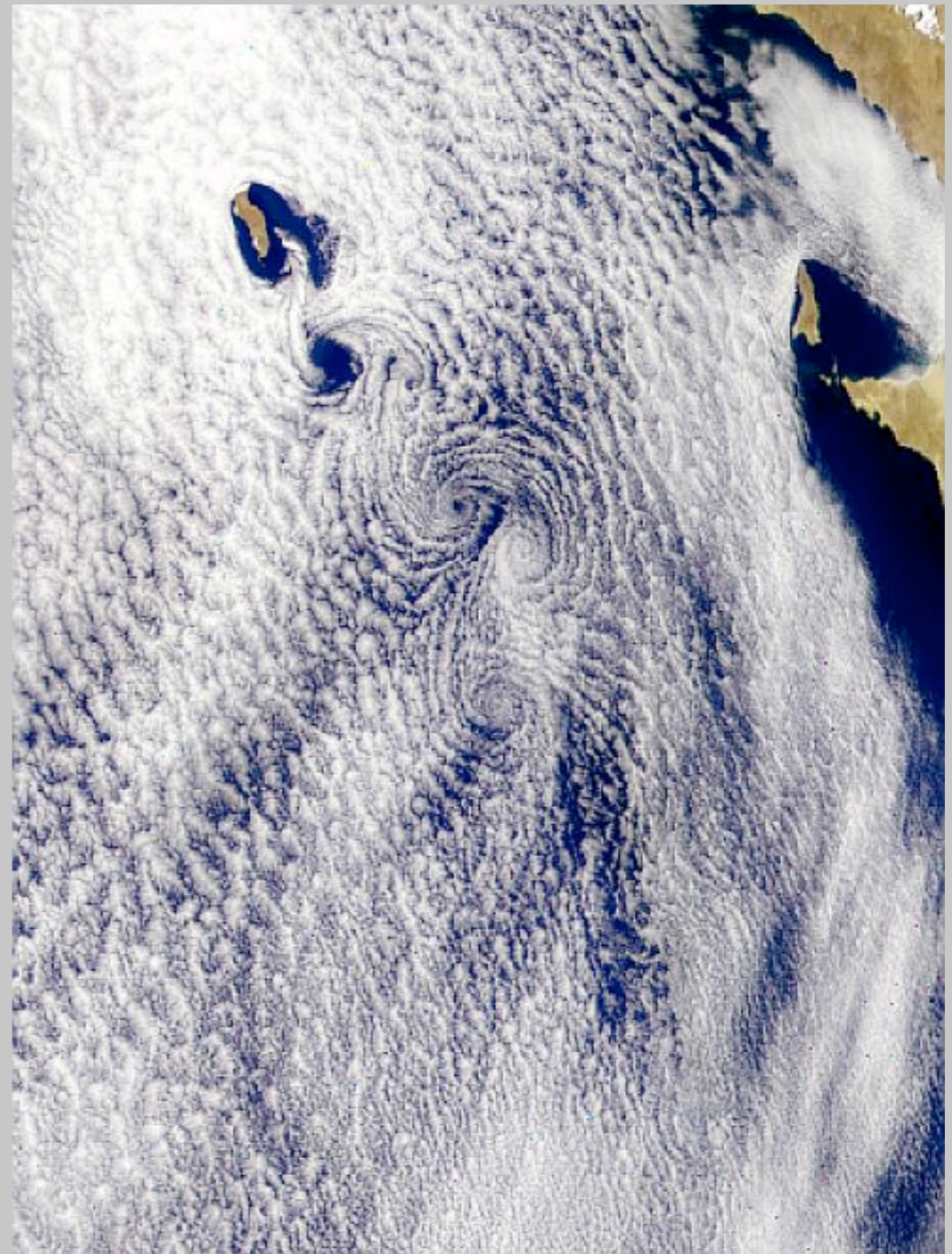
Super-Parameterization™

- ◆ Embed 2D Cloud System Resolving Model (CSRМ) in each GCM column, with periodic boundary conditions.
- ◆
- ◆ Model subgrid clouds, radiation, dynamics and microphysics with 4 km horizontal resolution and 20 second timestep.
- ◆
- ◆ Include cloud-radiation interactions using the Independent Column Approximation *on the cloud scale*.

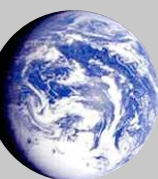
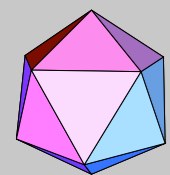


A summary of some results to date

- ◆ **Intra-seasonal, synoptic, and diurnal variability are more realistic with the MMF.**
- ◆ **Cloud-scale interactions between radiation and other processes are quite important for both low and high clouds.**
- ◆ **The MMF produces excessively strong precipitation systems over the tropical Western Pacific in the northern summer -- the GRS.**
- ◆ **The results obtained with the MMF are sensitive to the parameterized ice microphysics.**



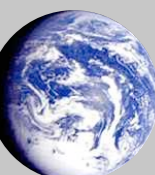
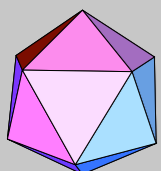
**Leo showed big differences
between 2D and 3D.**





Compared to what?

MMF	Conventional Parameterization
2D or Quasi-3D	1D
Periodic boundary conditions (or relaxation time scale)	Boundary whats?
Shallow convection and turbulence must be parameterized.	Same
Microphysics is simplified but the required input is in pretty good shape.	Microphysics is typically less sophisticated, and the required input (e.g., local vertical velocity) is not available.



Trajectory of an idea

**Perceived
merit**



*Peak of
Inflated Expectations*

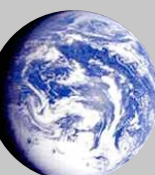
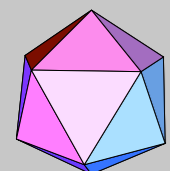
Eureka

*Trough of
Disillusionment*

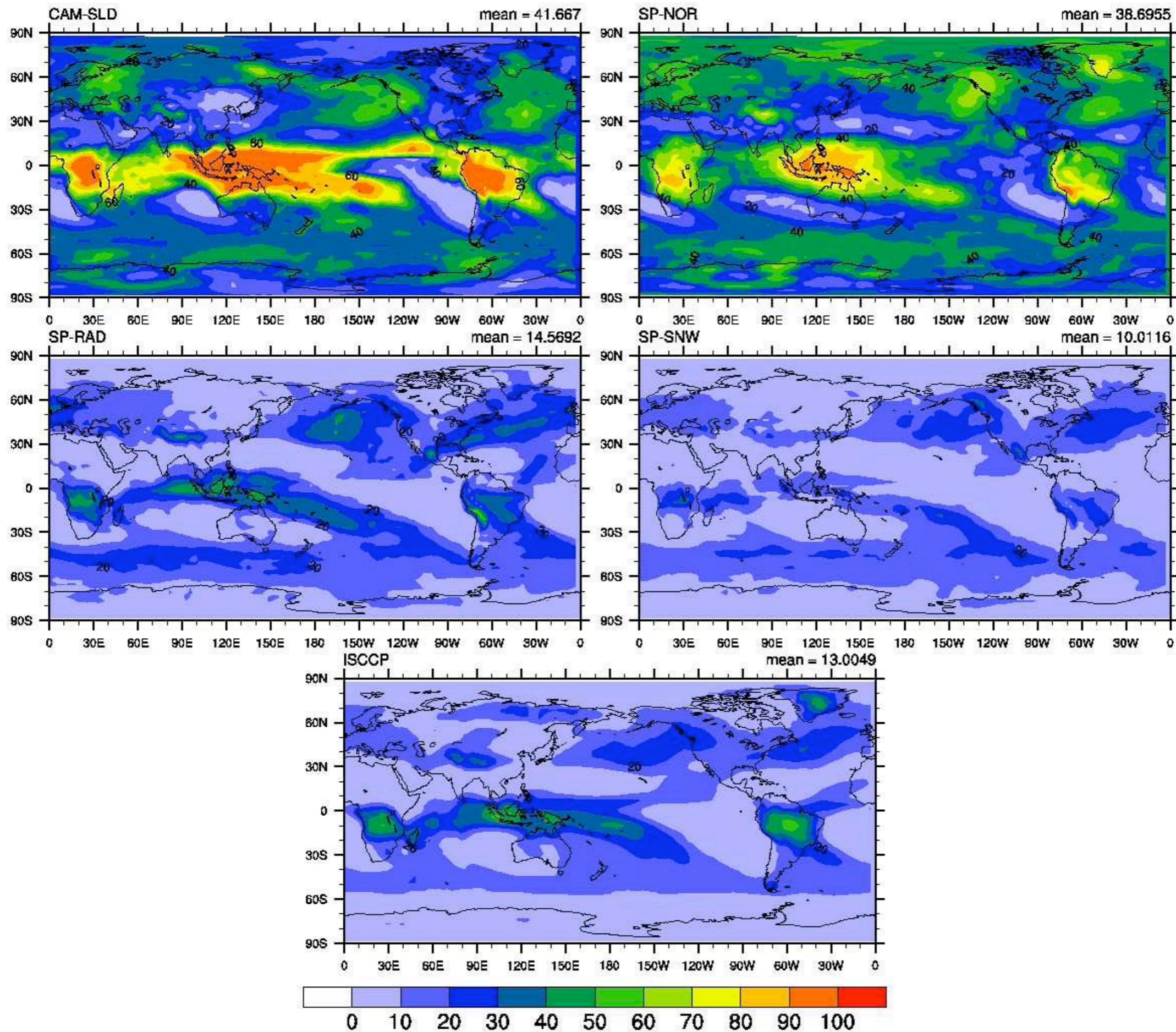
*Slope of
Enlightenment*

*Paradigm
Plateau*

Time

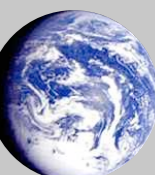
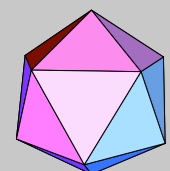


DJF High-Level Cloud Fraction



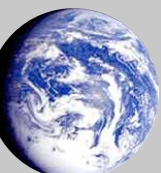
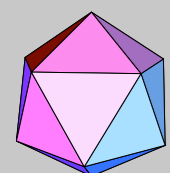
Hypotheses:

- ◆ **More realistic overlap gives more realistic results.**
- ◆ **Cloud-scale covariance between radiative heating and temperature matters for the development of the cloud field.**



Experiments

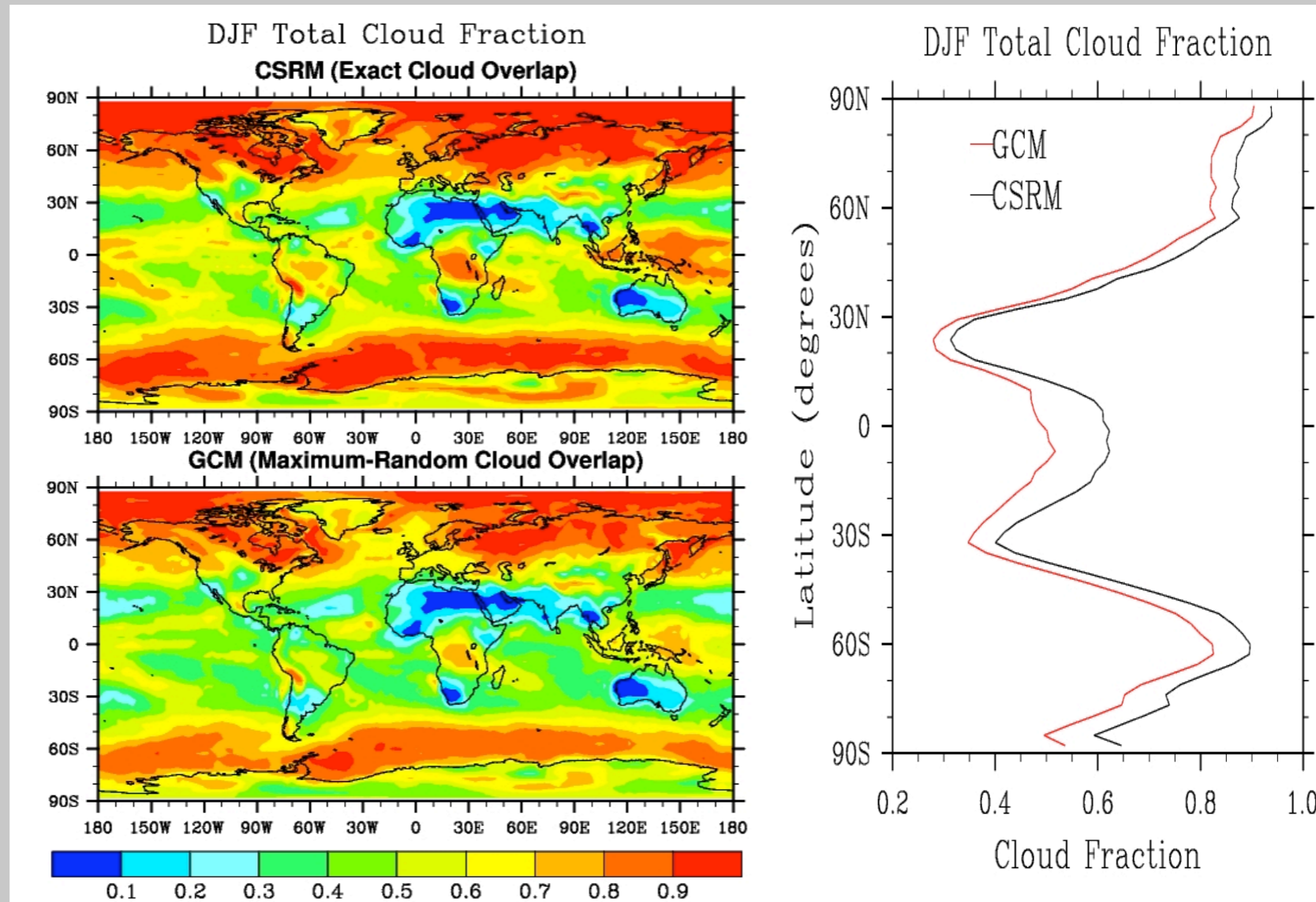
	<i>CSRM</i>	<i>GCM</i>	<i>Comment</i>
<i>Experiment 1 (like SP-RAD)</i>	CMO	CMO averaged	“Truth”
<i>Experiment 2</i>	CMO averaged	CMO averaged	Domain-averaged radiation, one value for domain, but a proper mean
<i>Experiment 3 (like SP-NOR)</i>	MRO	MRO	Domain averaged radiation, one value for domain but a biased mean
<i>Experiment 4</i>	CMO	MRO	Cloud-scale interactions recognized but a biased mean given to GCM
<i>Experiment 5</i>	Conventional GCM		Everything parameterized



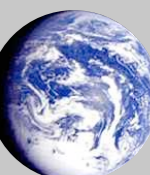
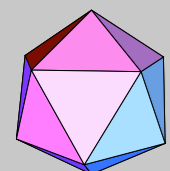
Diagnostic CMO vs MRO Cloud Fraction

Input is vertical profiles of CMO cloud fraction from Exp. 1.

Output is diagnostic calculation of MRO cloud fraction.

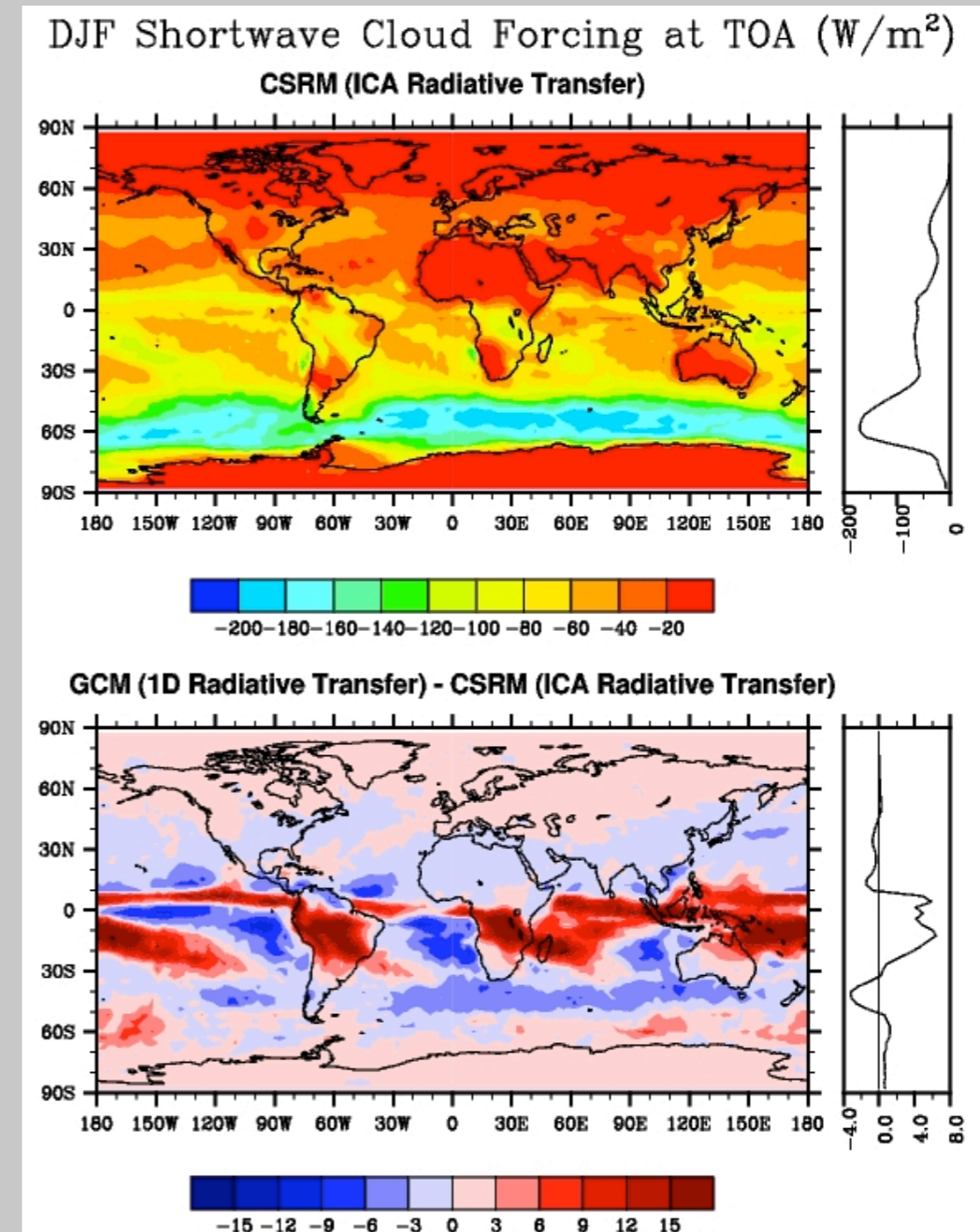
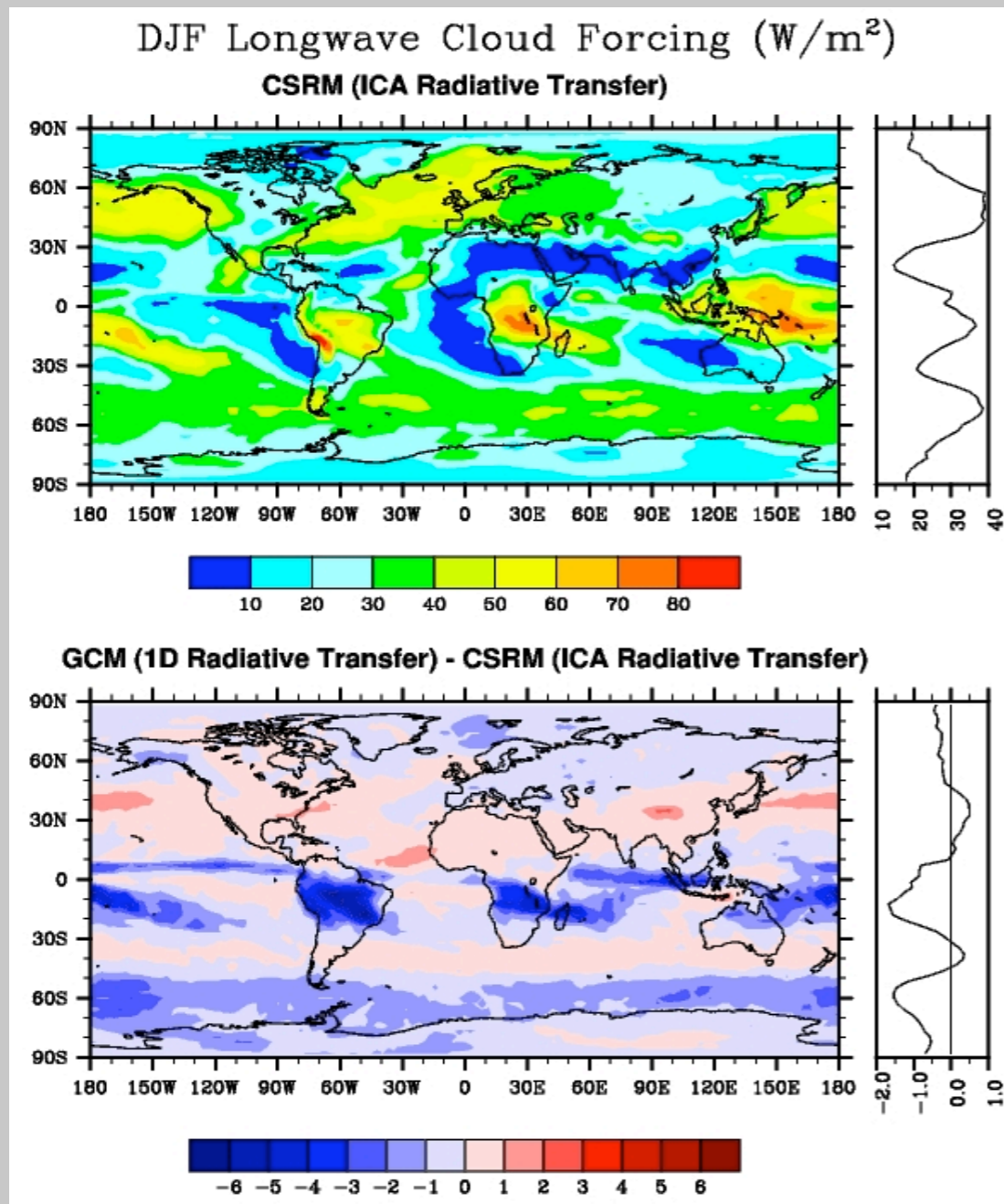


Used diagnostically, CMO gives more cloud.

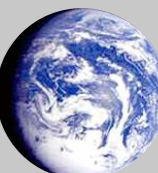
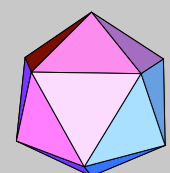


Diagnostic CMO vs MRO CRF

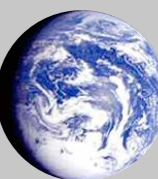
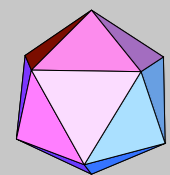
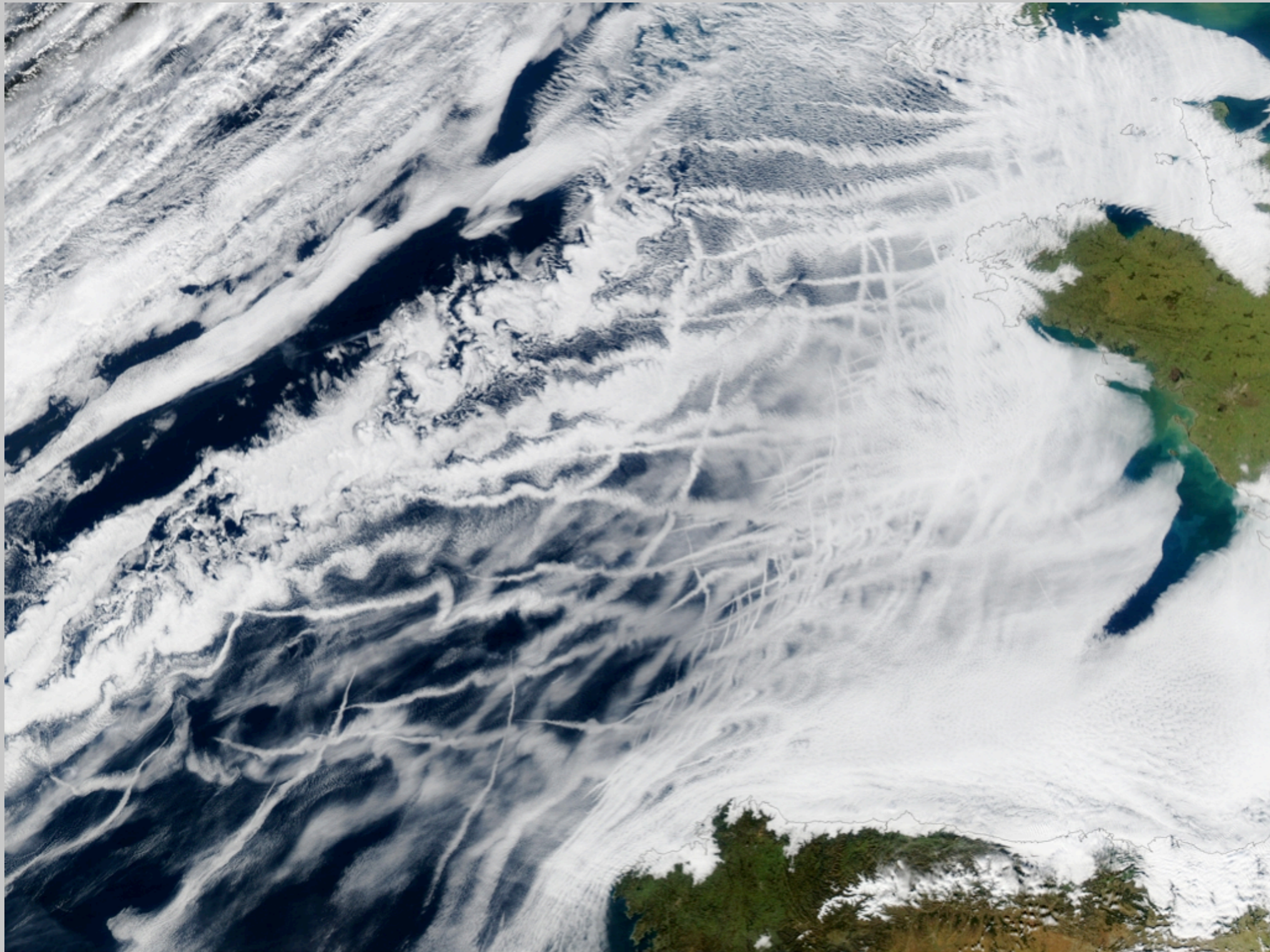
Input is vertical profiles of CMO cloud fraction from Exp. 1.
Output is diagnostic calculation of MRO cloud radiative forcing.



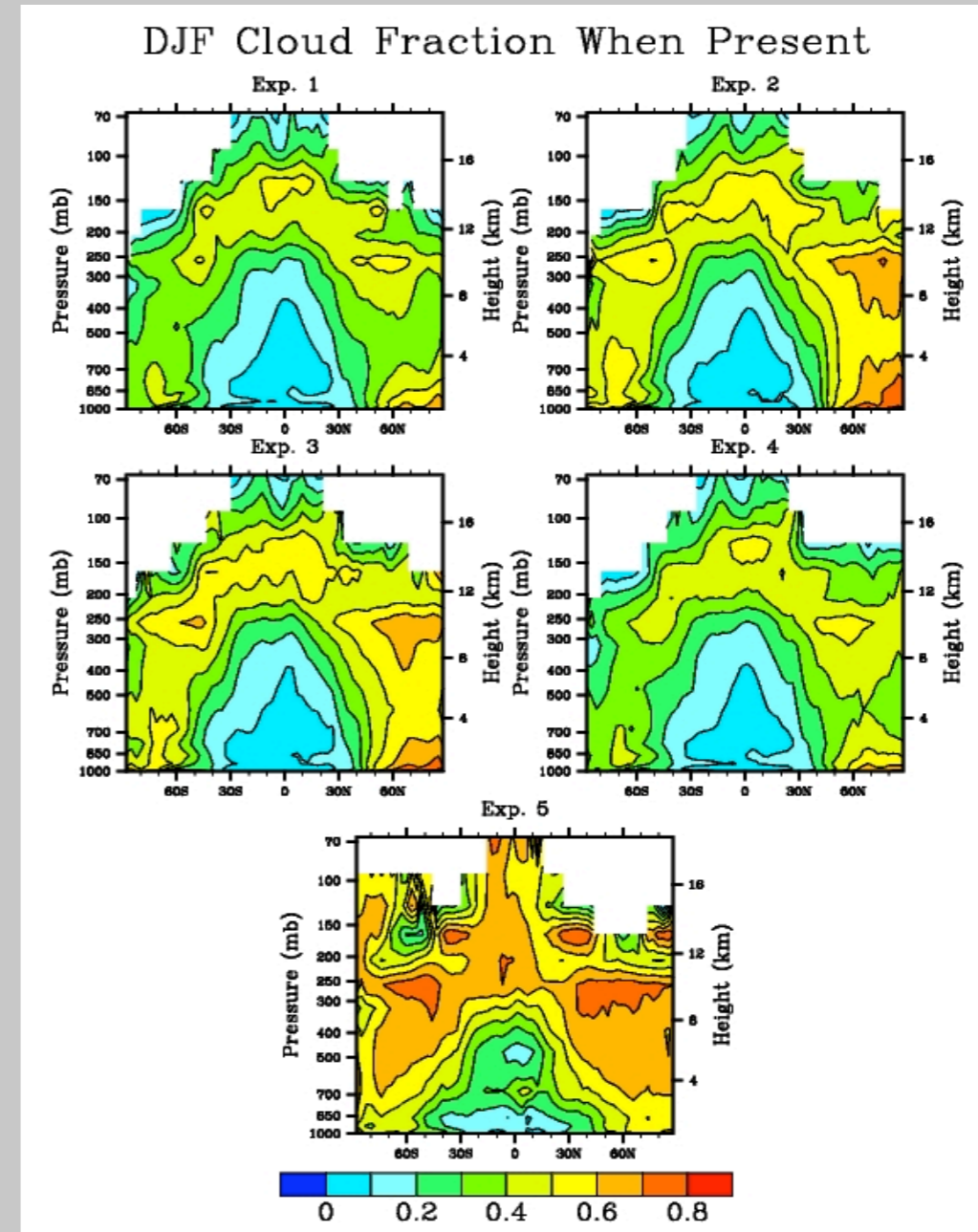
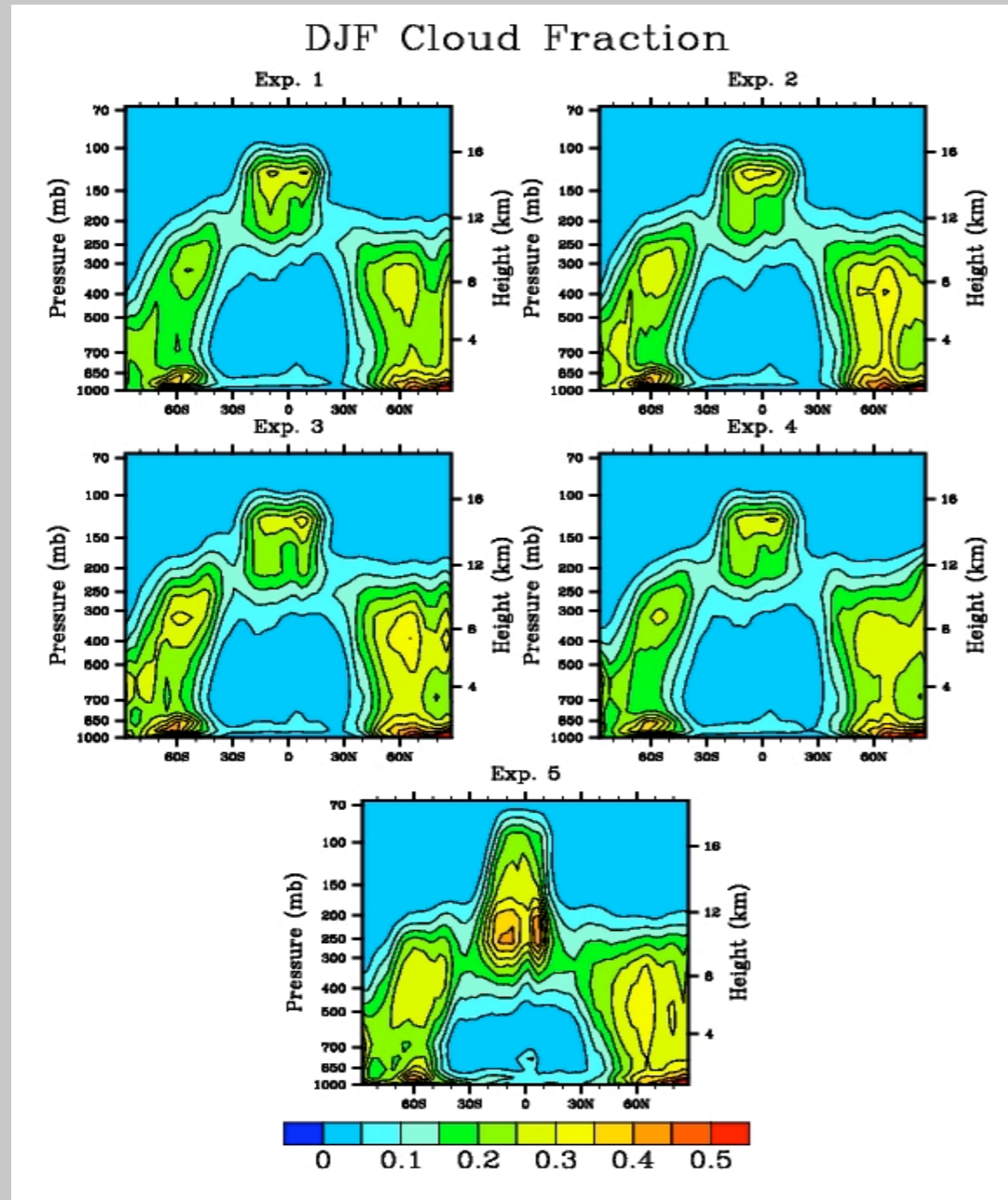
*Used diagnostically, CMO makes the CRF stronger,
consistent with its (diagnostic) higher cloud amount.*



Now on to the interactive results...

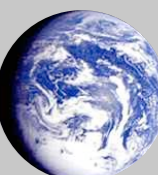
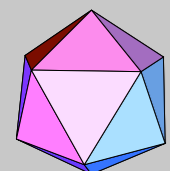


Cloud Fraction



Exps. 2 and 3 similar, with more cloud--*both non-interactive*.

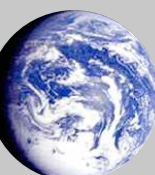
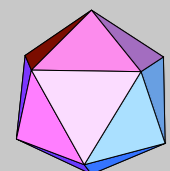
Exps. 1 and 4 similar, with less cloud--*both interactive*.



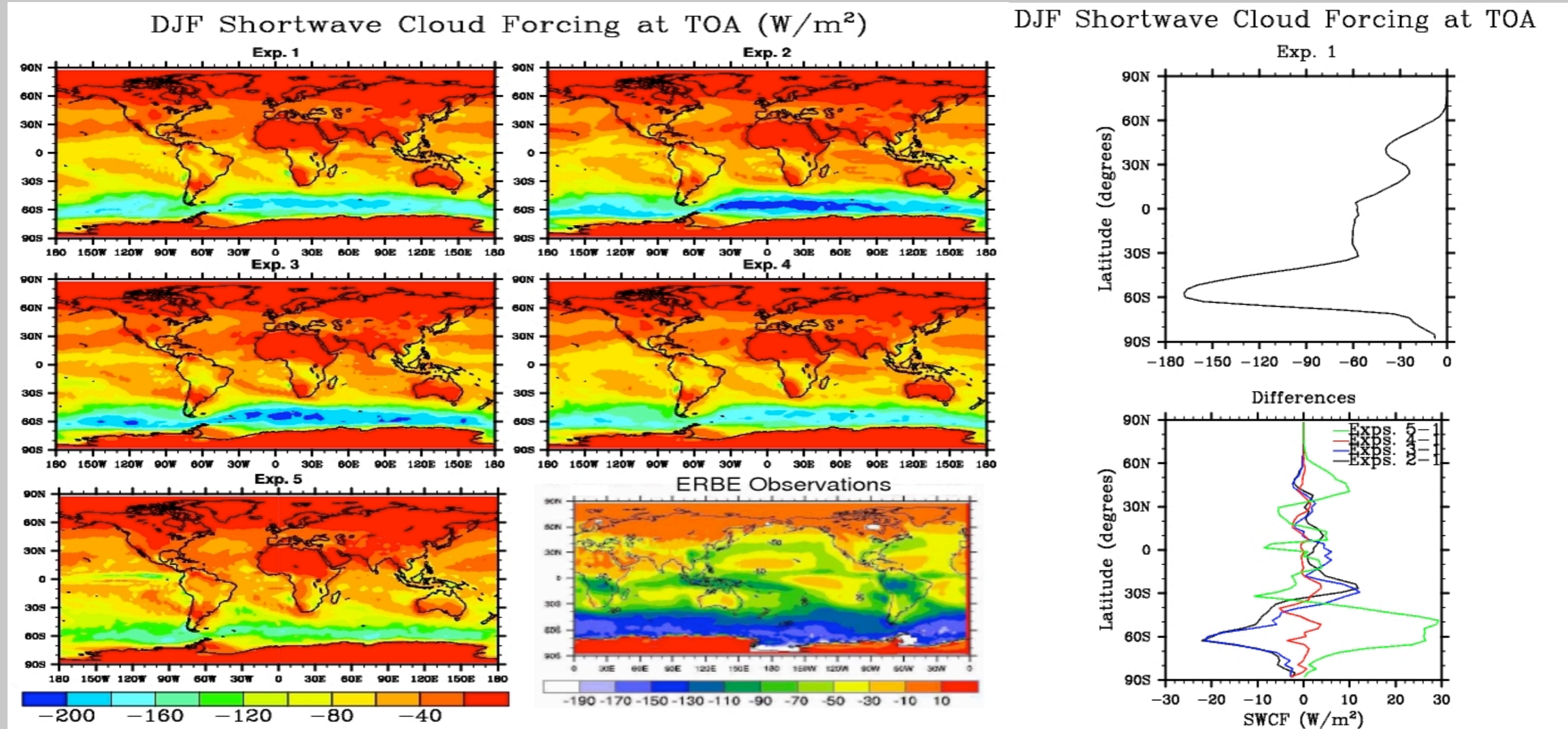
Also note that

**Diagnostically,
CMO gives more
cloud.**

**Interactively,
CMO gives less
cloud.**



Shortwave Cloud Forcing



Exps. 2 and 3 similar, with stronger SWCRF--*both non-interactive*.

Exps. 1 and 4 similar, with weaker SWCRF--*both interactive*.



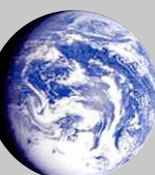
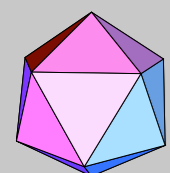
Take-home point

**Diagnostically,
CMO gives more
SWCRF.**

**Interactively,
CMO gives less
SWCRF.**

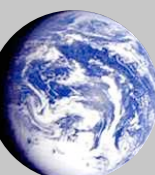
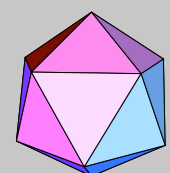


The differences are mostly due to ice clouds.

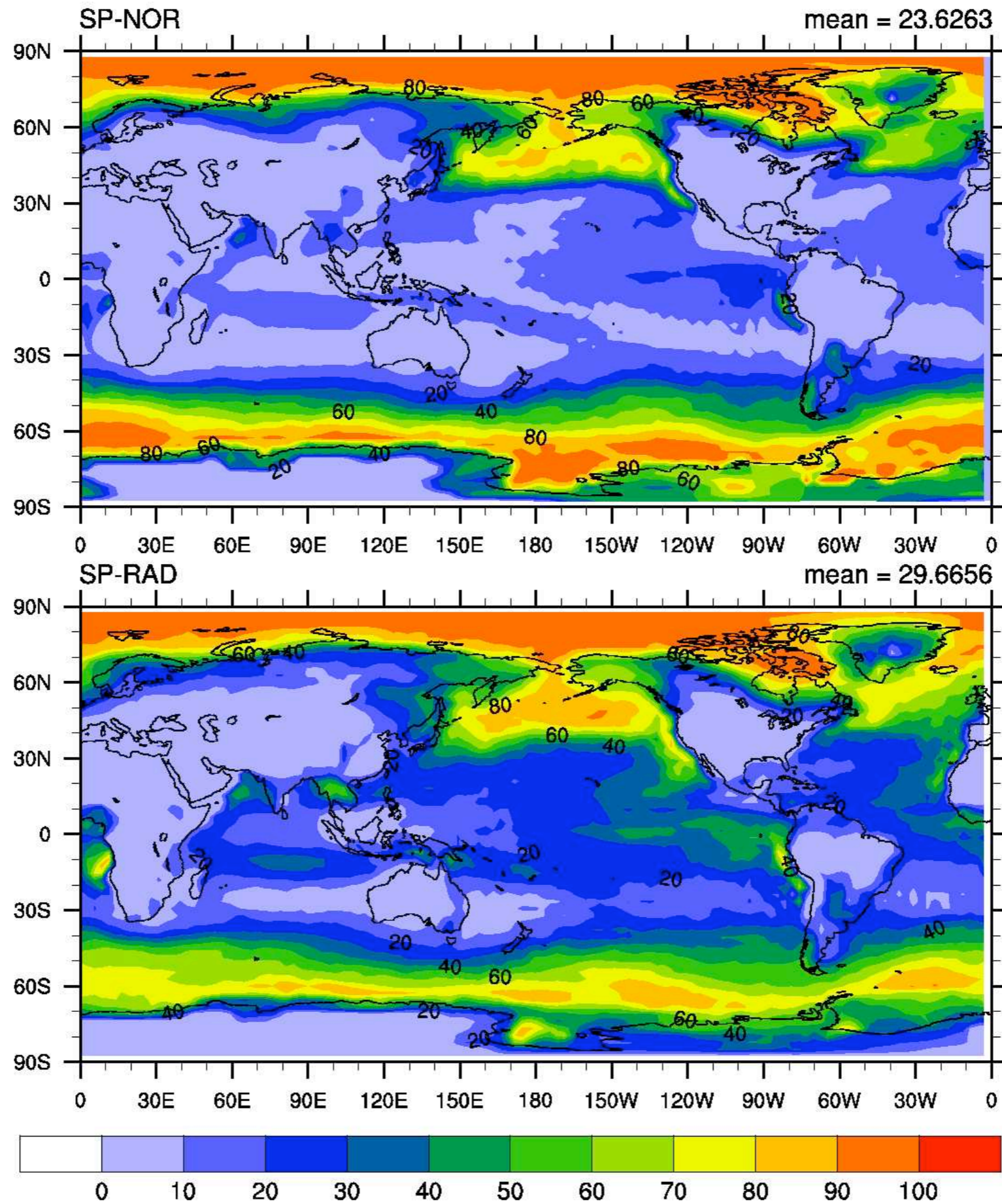


Cirrus summary

- **These experiments show that cloud-scale interactions between radiation and ice clouds are important for total cloud amount and SWCRF.**
- **This implies an important role for cloud-scale dynamics, and is consistent with studies by Dave Starr and others.**

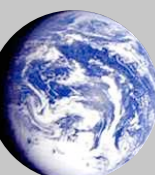
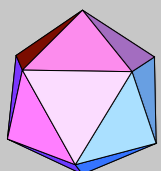
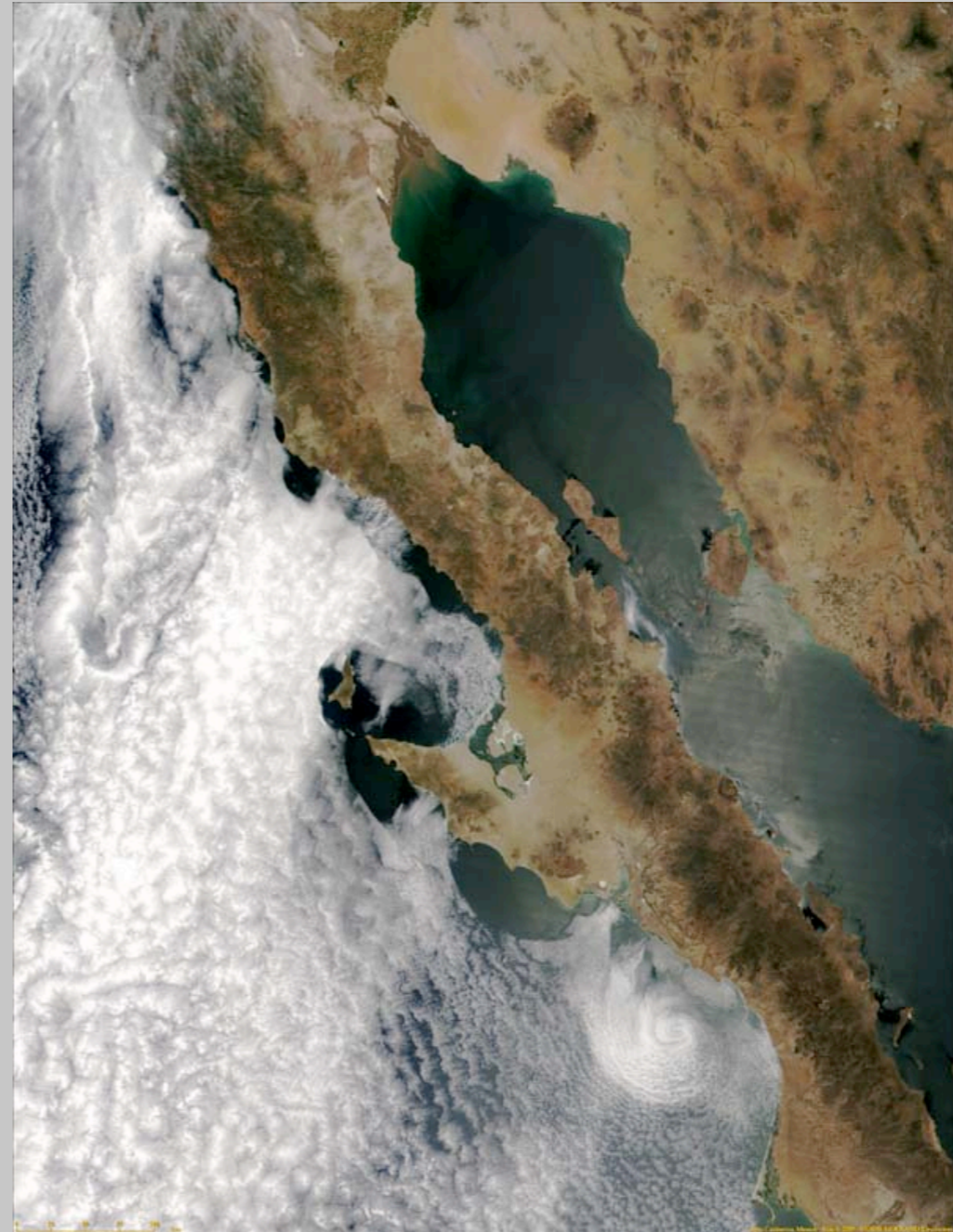


JJA Low-level Cloud Fraction



Why are stratocum so sensitive to the high-resolution radiation calculation?

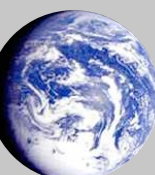
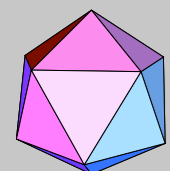
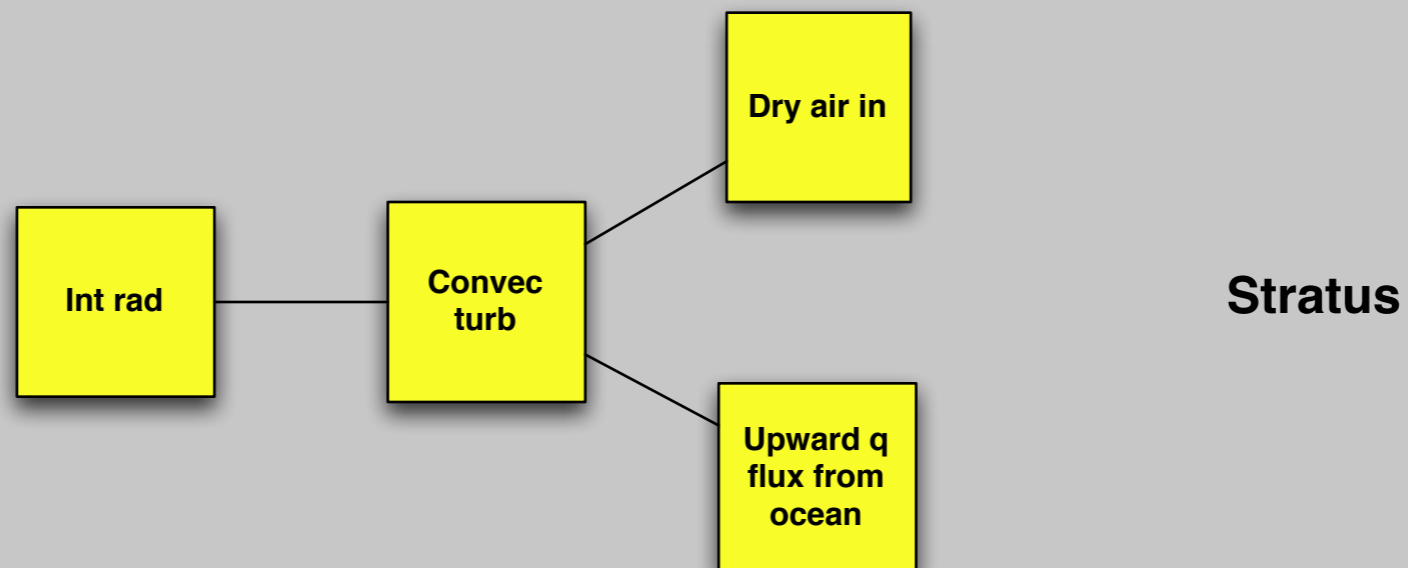
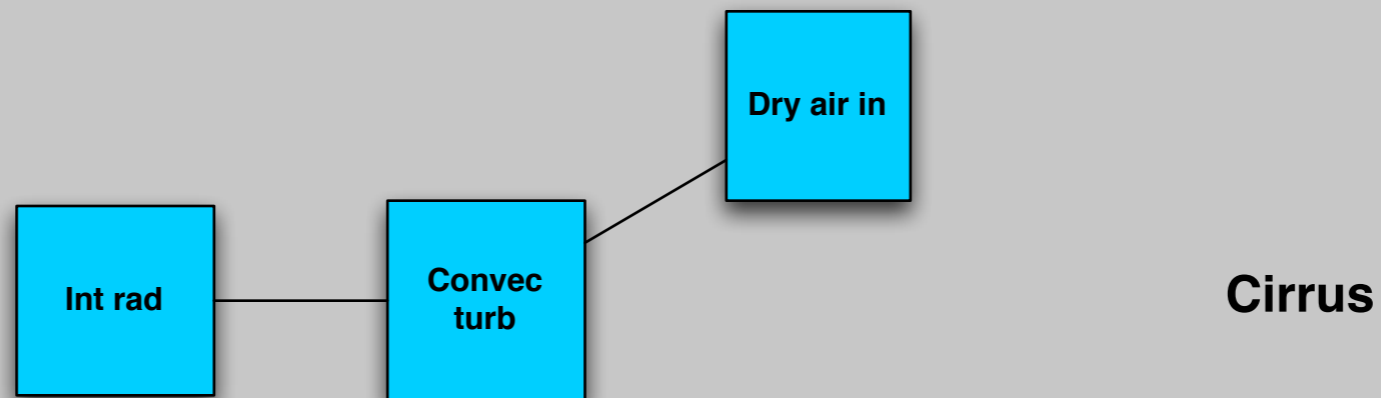
- ◆ **Lilly (1968) explained this in terms of radiatively driven turbulence and convection in the cloud layer.**
- ◆ **Convection transports moisture upward and so contributes to the maintenance of the cloud.**



Stratus and cirrus

Interactive radiation makes cirrus cloudiness decrease and stratus cloudiness increase.

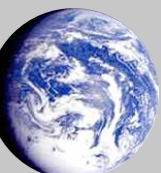
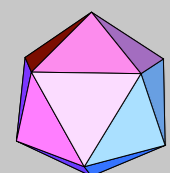
Why the difference?



Plug-and-pray?



Models should be as modular as possible but not more so.



What drives paradigm shifts?

Funerals



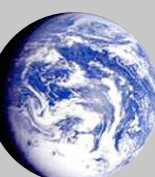
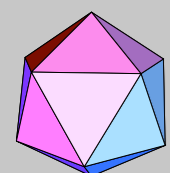
New observations



Faster computers



Inspiration



Conclusions

- ❖ **Processes interact on small space and time scales, and it matters.**
- ❖ **Future parameterizations will have to be unified.**
- ❖ **Our results provide an example of how an MMF can be used to learn something that could not have been learned with a conventional GCM.**

